COST COMPARISON OF ALTERNATIVE AIRFIELD SNOW REMOVAL METHODOLOGIES

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Introduction

- Commercial aviation helps generate more than 5% of U.S. Gross Domestic Product (GDP) and more than 10 million U.S. jobs
- In early 2014, there were more flight cancellations than in the previous 25 years with approximately 5.5% of scheduled flights being cancelled

Image Courtesy: *The Fox News*

Introduction: Motivation for this Study

- Heated Airport Pavements
- Task 1-A: to investigate the relative energy and monetary needs to remove snow from a slab by conducting an energy and financial viability analyses

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Research Projects

Heated Airport Pavements

Project Duration

08-14-2013 to 06-30-2015

Project Summary

Maintaining operational safety and status of airport runways during snowfall events is a challenging issue that many airports are grappling with. According to FAA Advisory Circular 150/5370-17 (dated 2011), most transport category aircraft are prohibited from operating on runways covered by untreated ice or by more than 1/2 inch of snow or slush, although the limits vary with aircraft types. The surface traction of pavement is dramatically influenced by frozen precipitation in the form of ice, snow, or slush. This can seriously hamper smooth air traffic management operations and cause traffic delays at other airports. It is imperative that both small and large airports maintain operational status during snowfall events to support the existing operations as well as the FAA's NextGen concept as mentioned in the Airport Technology Research Plan for the NextGen Decade (dated January 2012).

Traditional deicing methods involving sand/chemical mixtures pose not only environmental concerns, but also can potentially result in creating Foreign Object Damage (FOD) to aircraft engines. Additionally, the costs of owning and operating snowplows can be substantial for many general aviation airports. Innovative concepts such as heated pavement systems, which can use either electric or renewable energy as a heat source, show good potential by providing enough heat to keep the surface temperature of the runway above freezing so that any frozen precipitation melts upon contact. The FAA has expressed an interest in investigating the concept of heating pavements at airports to assist with snow and ice removal. Recognizing the limitations of current practice and research on heated pavement technology, prudent use of heat on select areas of airfield pavements should be considered. Heated pavement areas to be considered should be limited to those areas where: (1) Benefits justify cost of installation and operation; (2) Mechanical methods of snow removal are difficult to accomplish or are not cost effective; (3) Operational safety is a factor; (4) Delays at critical locations within the airport cannot be tolerated; and (5) Use of chemical deicers is restricted/limited. The FAA has suggested that attention should be focused initially on the parking ramps. Potential benefits include greater safety for crews and passengers, both on the ground and in aircraft, more efficient turnaround of aircraft because conventional plowing is difficult under and around a parked aircraft.

Over the past decade, a number of national and international research studies have investigated the use of alternative energy for anti-icing, deicing, and snow removal from bridge decks and highway pavements. Reportedly some efforts have been investigated using geothermal hydraulic and battery based electrical systems with limited success. The FAA has expressed concern that if any system is to be adopted it must be cost effective, both in terms of installation and operating costs.

In this project we propose a 3-pronged approach to investigate the efficacy and cost effectiveness of new heated pavement technologies. We propose to investigate: the relative energy and monetary needs to remove snow from a slab by conducting an energy and financial viability analyses under Task 1-A; a hybrid approach combining electrically conductive concrete with lotus-leaf-inspired super-hydrophobic surfaces under Task 1-B; and the application of nano-coatings of low temperature phase change materials with the intent of preventing ice and slush formation under Task 1-C. We anticipate that these three tasks will run in parallel. Below, we briefly describe each task in detail.

FAA Technical Point of Contact

Charles Ishee - *Federal Aviation Administration* (charles.ishee@faa.gov)

PEGASAS

Introduction

- Commercial airports with annual airline operations of more than 40,000 are required to clear from the priority areas within half an hour of 1 inch of snowfall.

FAA AC No. 150/5220-20A

Airport Snow and Ice Control Equipment

This advisory circular (AC) provides guidance to assist airport operators in the procurement of snow and ice control equipment for airport use.

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Airport Snow and Ice Control Equipment	**Date:** DRAFT **Initiated by:** AAS-100	**AC No:** 150/5220-20A **Change:**

1. **Purpose**. This advisory circular (AC) provides guidance to assist airport operators in the procurement of snow and ice control equipment for airport use.

2. **Cancellation**. This AC cancels AC 150/5220-20, dated 6/30/1992.

3. **Vehicle movement coordination**. Vehicle movements on airport operational areas shall be conducted in accordance with 14 Code of Federal Regulations (CFR) Part 139.329 and appropriate provisions of AC 150/5200-30, Airport Winter Safety and Operations. To help minimize the potential for runway incursions, see Airport Cooperative Research Program (ACRP) Synthesis #12, Preventing Vehicle – Aircraft Incidents during Winter Operations and Periods of Low Visibility, for guidance in the areas of but not limited to communications, fatigue, and operational protocols.

4. **Application.** The Federal Aviation Administration (FAA) recommends the standards and recommendations in this AC for use in the purchase of snow removal and ice control equipment. In general, use of this AC is not mandatory. The standards and recommendations contained in this AC may be used by certificated airports to satisfy specific requirements of Title 14 CFR Part 139, Certification of Airports, subparts C (Airport Certification Manual) and D (Operations). Use of this AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and/or with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, Policies, Standards, and Specifications, and PFC Assurance No. 9, Standards and Specifications.

5. **Use of metrics.** Throughout this AC, customary English units are used followed with "soft" (rounded) conversion to metric units. The English units govern.

Introduction: Traditional Snow Removal Strategies

- Conventional strategies include both mechanical methods and chemical methods. Mechanical methods include use of snow plows/blowers, snow brooms, and sweepers
- Mechanical methods of snow removal might be very time consuming as they operate at relatively slow speeds and may interfere with aircraft operations
- Wet snow and ice can develop a strong bond with the pavement which reduces the efficiency of snow removal equipment greatly
- A major drawback is that they remove snow from the surface and do not focus at the point of bonding
- Mechanical methods can also damage the pavement and embedded lighting fixtures. Increasing labor needs raises costs and safety concerns

Introduction: Traditional Snow Removal Strategies

- Chemical treatments include solid chemical dispersal and liquid spraying equipment using a variety of de-icing and anti-icing chemicals.
- Traditional deicers have potential negative environmental impacts and FOD concerns

Image Courtesy: *DuPont Tate & Lyle*

Introduction

- Efficient removal of snow and ice from the airport pavements is essential
  - for maintaining safe operations for both aircraft and ground operations
  - Increasing the number of operations
  - for keeping the airport functional

Image Courtesy: *The Guardian*

Image Courtesy: *The Daily Mail (UK)*

- Snow and ice removal should also be efficient to reduce cost.

Introduction: Heated Pavement Strategies

- Heated pavement systems remove snow and ice using the heat provided by embedded electric cables or hydronic tubing.

"The FAA recommends heated pavement systems only for locations in the AOA where:

- *Benefits will justify the cost of installation and operation,*
- *Mechanical methods are difficult,*
- *Use of chemicals may be limited,*
- *Operational safety is a factor, and*
- *Delays at critical locations cannot be tolerated."*

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRSIDE USE OF HEATED PAVEMENT SYSTEMS
Date: 3/29/2011
Initiated by:
AC No: 150/5370-17
Change:

1. **PURPOSE.** This Advisory Circular (AC) establishes minimum performance requirements for the design, construction, inspection, and maintenance of heated pavement systems for use in the Aircraft Operations Area (AOA). The AC includes:

   a. Principles of operation and applications.

   b. Design process, including heat requirements, formulas, and sample calculations.

   c. Perspective locations and characteristics.

   d. Design considerations for electric and hydronic systems, including system controls.

   e. System performance requirements and specification template.

   f. System construction requirements and specification template.

   g. Inspection and maintenance requirements.

2. **APPLICATION.** The FAA recommends the guidelines and standards in this AC for heated pavement systems for airside applications. In general, use of this AC is not mandatory. However, use of the AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, "Policies, Standards, and Specifications," and PFC Assurance No. 9, "Standards and Specifications." Airports certificated under Title 14 Code of Federal Regulations, Part 139, Certification of Airports (Part 139), must use the specifications in this AC for pavement construction projects involving heated pavement systems for airside applications.

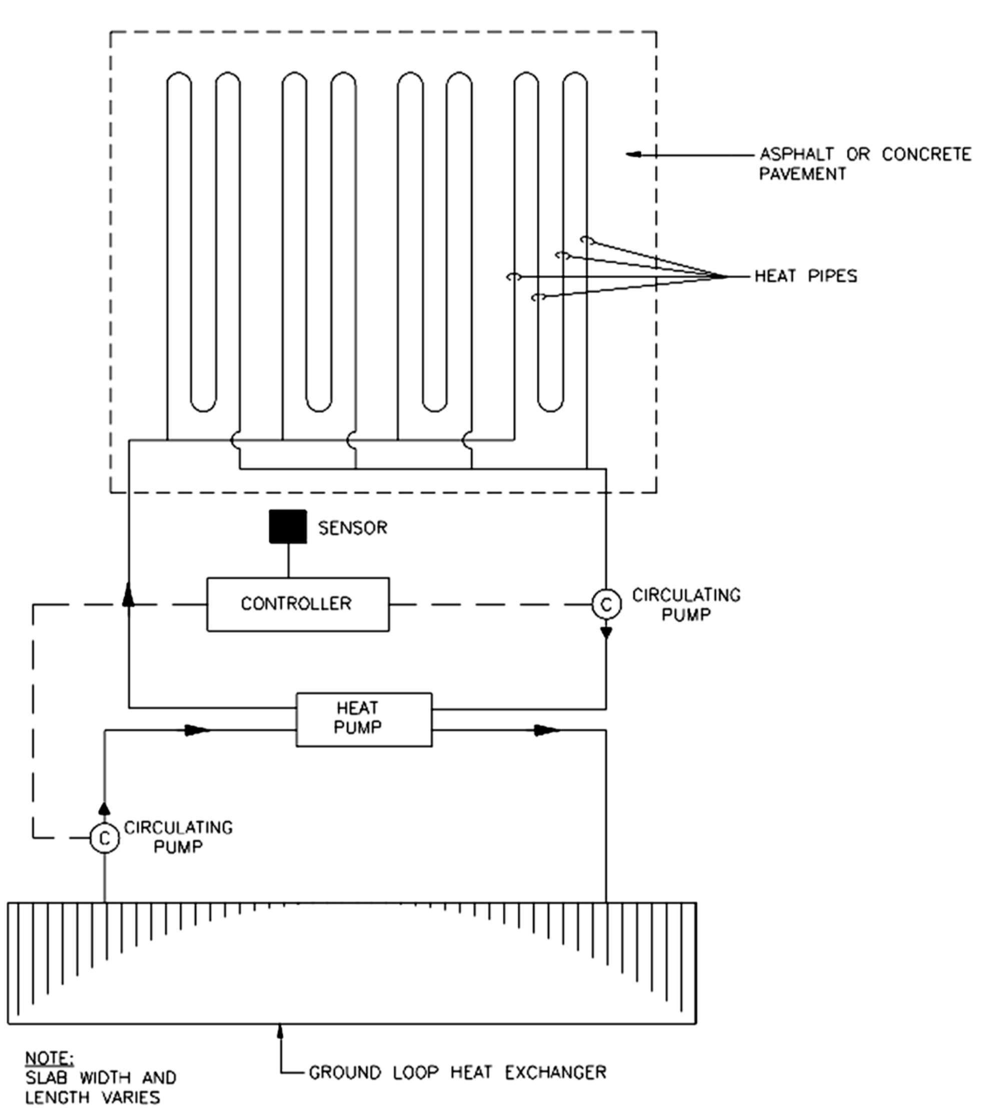
3. **PLANNING.** All heated pavement system project requests, regardless of size and scope, must be coordinated with the Office of Planning and Programming for AIP eligibility determination.

4. **COPIES OF THIS AC.** This AC is available on the FAA website (www.faa.gov).

Director of Airport Safety and Standards

Introduction: Heated Pavement Strategies

Hydronic
Heated
Pavements



Source: *FAA AC No. 150/5370-17*

Objectives

- To assess and compare costs incurred due to melting of snow at ramp and gate areas:
  - Hydronic heated pavements Vs conventional snow removal methods

Image Courtesy: *The Wall Street Journal Online*

Image Courtesy: *Gadling*

- Preliminary case study using available data from Des Moines International (DSM) airport in Iowa

Methodology

- Overall methodology

SELECT AIRPORT

WEATHER CONDITIONS

ENERGY REQUIREMENT TO MELT SNOW/ICE

PASSENGER AND DELAY STATISTICS

COST FOR SNOW REMOVAL USING CONVENTIONAL STRATEGIES

COST OF SNOW REMOVAL USING HEATED PAVEMENT STRATEGIES

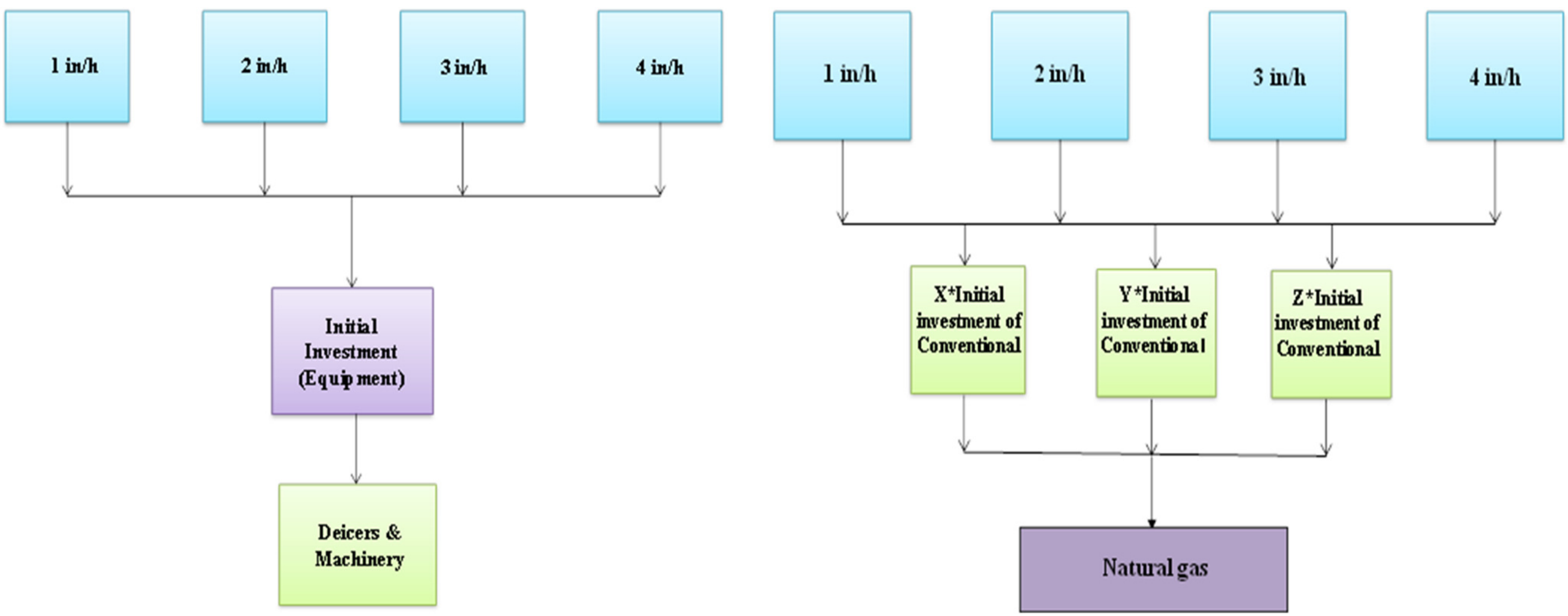
COMPARISON OF RESULTS FOR A 20 YEAR PERIOD

Methodology

- Study Assumptions
  - Analysis is carried out for a 4,131,847 ft^2 ramp area at DSM airport in Iowa
  - Design life: 20-year time period
  - Discount rate: 5%
  - Maintenance cost = 1% of (operation + installation) costs
  - Salvage value = 10% of initial cost
  - Energy source for heated pavements: natural gas or electricity
  - Study period: four winter months (November to February)

Methodology

- Selected scenarios for cost comparison



Conventional strategies **Hydronic heated pavements**

Methodology

- Weather Conditions
  - Based on weather patterns at DSM airport, four snowfall scenarios were considered

Scenario	Snowfall (in./h)
Moderate	1.0
High	2.0
Very high	3.0
Severe	4.0

- Energy Requirements to Melt Snow
  - The steady-state energy balance equation for required pavement heat output (q_o) in Btu/ h•ft^2 as presented in FAA Advisory Circular AC 150/5370-17
  - $q_o = q_s + q_m + A_r (q_e + q_h)$
    - Where:

      q_s = sensible heat transferred to the snow (Btu/ h•ft^2)

      q_m = heat of fusion (Btu/ h•ft^2)

      A_r = snow-free area ratio must equal 1 for areas with aircraft operations

      q_e = heat of evaporation (Btu/ h•ft^2)

      q_h = heat transfer by convection and radiation (Btu/h•ft^2)

Methodology

- For hydronic heating systems, the temperature of the fluid can be calculated using:

$$tm = 0.5qo + tf$$

Where:

tm = average fluid temperature, °F

tf = water film temperature (°F), accepted as 33°F

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Methodology

- Energy Requirements to Melt Snow

Snowfall in an hour (in/h)	Sensible heat (BTU/ h·ft^2)	Heat of fusion (BTU/ h·ft^2)	Heat of evaporation (BTU/ h·ft^2)	Heat transfer by convection and radiation (BTU/h·ft^2)	Pavement heat output (qo) BTU/ h·ft^2	Average fluid temperature °F
1	3.12	74.62	0.25	57.20	135	114
2	6.76	149.24	0.25	57.20	213	114
3	10.14	223.86	0.25	57.20	291	114
4	13.52	298.48	0.25	57.20	369	114

Methodology: Costs for Snow Removal by Conventional Strategies

Cost for Clearing Snow using Conventional Strategies

- Airports
  - Initial/ Capital Cost
    - Cost of snow removal equipment (SRE)
  - Recurring Cost
    - Maintenance cost of SRE
    - Cost of fuel spent in running the SRE
    - Cost of deicing agents
    - Labor cost

Methodology: Estimation of Indirect Costs

- Costs to Airlines Due to Delays
  - Indirect Costs
    - Cost of fuel
      - Ground delays
      - Mid-air delays
    - Extra cost incurred towards flight crew

Methodology: Estimation of Indirect Costs

- Passenger and Delay Statistics
  - Annual passenger enplanements
  - Annual operations
  - Delay statistics from Bureau of Transportation Statistics (BTS)
  - Delay minutes were calculated
  - Average weather related delays (%) for a period from November to February were calculated
  - The delay values are based on the 2013-2014 winter

Methodology: Estimation of Indirect Costs

- Costs to Passengers Due to Delays
  - Passengers suffer major delays during snow storms leading to a loss of time
  - Tried to measure the lost time in monetary terms
  - Passengers can be grouped into two categories, travelling for business and travelling for personal purposes or leisure and have been assigned different monetary values
  - These values have been converted to 2014 dollar values

Value of time (per hour)	Cost per hour
Personal	**$31.96**
Business	**$55.00**

GRA, Incorporated, "Economic Values for FAA Investment and Regulatory Decisions, A Guide", Final Report for U.S. Federal Aviation Administration, Jenkintown, PA, 2011.

Methodology: Costs for Snow Removal by Heated Pavement Strategies

Heated Pavement Systems

- Initial Costs of Installation
  - Due to lack of available data approximate costs were estimated by equating the BC ratio to 1 (break-even point)
  - Analysis was carried out by taking three initial cost scenarios:
    - One at the break-even point, one at a 50% lower and the other at a 50% higher value of the break-even point
  - To better approximate the results, a hydronic heating company was contacted for a price quote
    - A low and high cost scenario of $\$12/ft^2$ and $\$22/ft^2$, respectively, were assumed to carry out the BCA

Methodology: Costs for Snow Removal by Heated Pavement Strategies

Heated Pavement Systems

- Recurring Costs
  - Recurring cost here refer to the costs incurred to operate the heated pavement systems over a 20-year period
  - It consists of the cost of natural gas (for instance) required to produce the required BTU/h of heat output
  - The amount of natural gas required was calculated according to the heat output requirement

Methodology: Cost Comparison

Benefit Cost Analysis (BCA)

- Economic technique that allows comparison of investment alternatives having different cost streams
- Incorporates initial and discounted future agency, user, and other relevant costs over the design life of alternative investments
- Attempts to identify the best value for investment expenditures

Methodology: Cost Comparison

BCA Framework

- Analysis Period
  - The analysis period for BCA must be sufficiently long such that each alternative pavement strategy includes at least one future rehabilitation event. FAA pavement design practice requires us to use a 20-year design life period
- Discount Rate
  - The discount rate is a very important piece of the BCA framework because it can influence the results of the analysis significantly.
  - It represents the real value of money over time and is used to convert future costs to present-day costs. The discount rate is a function of both the interest rate and the inflation rate.
  - A discount rate of 5% was used (sensitivity analyses will be carried out for different discount rates)

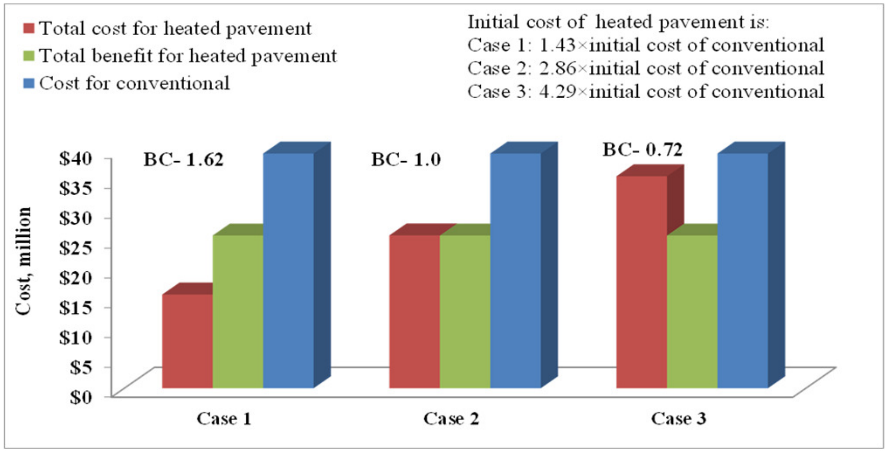
Results and Discussions

- Comparison of Results
  - The costs were compared by calculating the present value of the costs/benefits for a 20-year period
- Benefit cost (B/C) ratio:

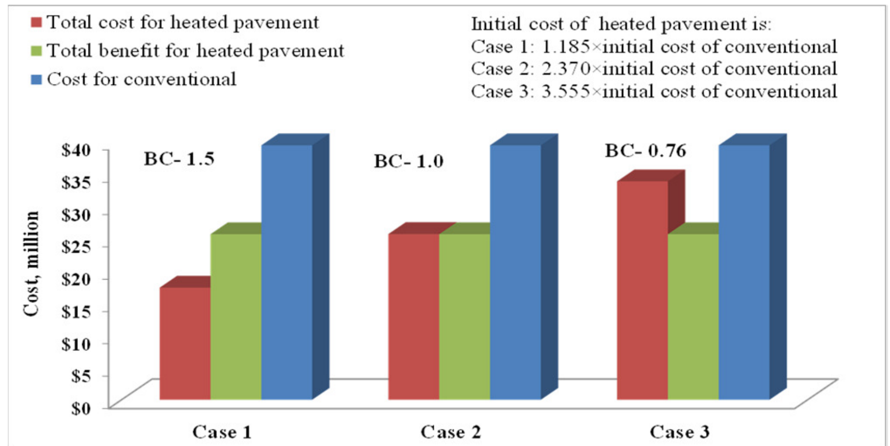
$$\frac{\text{Summation of all benefits over the analysis period}}{\text{Summation of all costs over the analysis period}}$$

Results and Discussions

Costs comparisons and Benefit-Cost Ratio for Conventional and Hydronic Heated Pavements for a Snowfall of (a) 1 in/h; (b) 2 in/h; (c) 3 in/h and (d) 4 in/h



(a)



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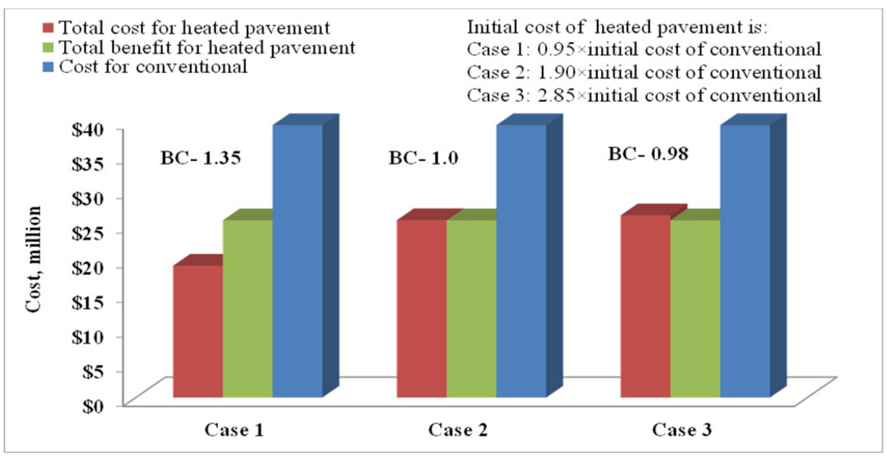

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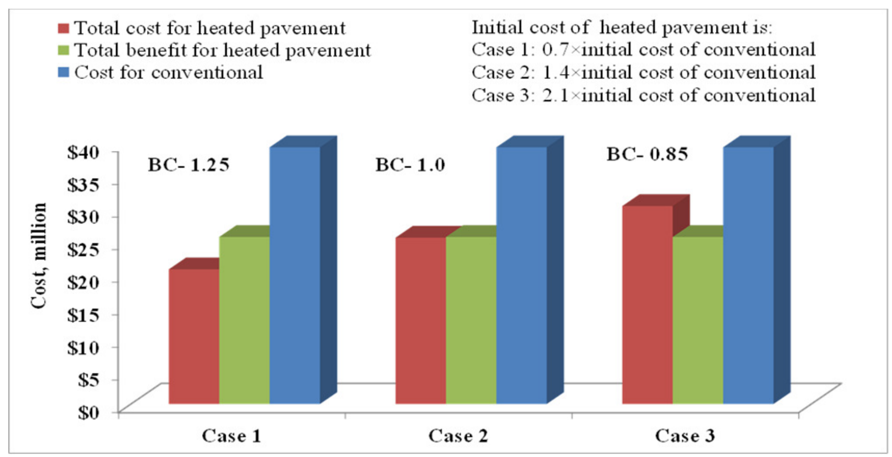

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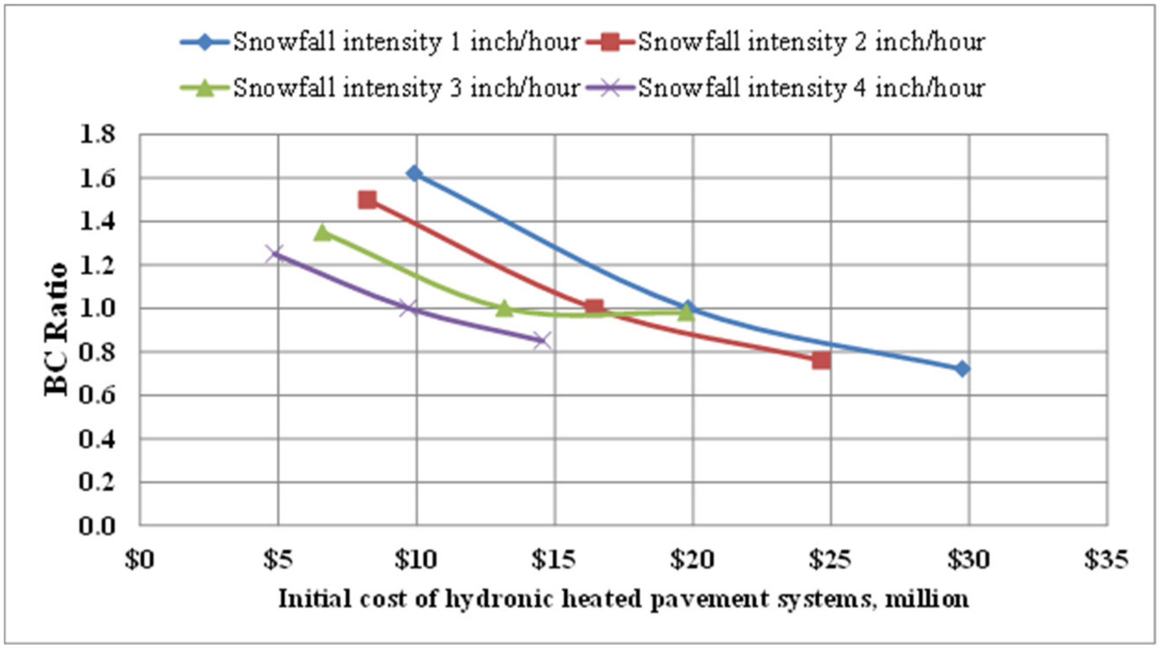
Results and Discussions

- Comparison of Results



Plot between the Benefit Cost Ratio and Initial Cost of Hydronic Heated Pavement Systems for Different Intensities of Snowfall for Des Moines International Airport

Summary- Key Findings

- Passengers are the most affected due to the delayed and cancelled flights in terms of monetary values
- Hydronic heated pavements have a lower operation cost but higher cost of installation
- The indirect or soft costs related to delays or cancellations which are borne by airlines, airports and passengers would greatly reduce with the use of heated pavement systems as they comprise of a major share in the total delay cost
- The high cost of installation of the heated pavement systems can be justified over a 20-year period especially for a high snowfall rate

Future Recommendations

- Future studies may focus on weather conditions at different airports to assess the financial viability of installing such heated pavements at respective airports.
- More accurate installation costs of the hydronic heated pavements could be estimated to get a close approximation of the viability of such heated pavement systems
- Additional soft benefits will be considered such as additional detailed delay costs (e.g., cost of cargo delay), safety and environmental benefits, and others.
- Comprehensive costs comparison of the use of heated pavement systems for taxiways, ramps and gates compared to the conventional methods.
- The economic analysis framework developed in this study could be extended to a life cycle cost analysis (LCCA) framework using a benefit cost ratio methodology as suggested by the FAA.

Thank You!

Questions & Comments?